The Cosmological Consequences of the Preon Structure of Matter

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Abstract

If the preon structure of quarks, leptons and gauge bosons will be proved then in the Universe during a relativistic phase transition the production of nonperturbative preon condensates has occured. Familons are collective excitations of these condensates. It is shown that the dark matter consisting of familon type pseudogoldstone bosons was undergone to two relativistic phase transitions temperatures of which were different. In the result of these phase transitions the structurization of dark matter and therefore the baryon subsystem has taken place. In the Universe two characteristic scales which have printed this phenomenon arise naturally.

The commonly accepted point of view on formation of Large Scale Structure (LSS) of the Universe is based on the assumption about de velopment after (LSS) of the Universe is based on the assumption about development after inflation period of homogeneous and isotropic Gausian scalar perturbations (perturbations of density). The post-recombination spectrum of these perturbations connects with initial perturbations by the transition function which depends on nature of dark matter very strong. The standard model predicts $\Omega_{total} = 1$ that is $\Omega_{CDM} + \Omega_{HDM} + \Omega_{baryon} + \Omega_{\Lambda} = 1$ in which large-mass objects are created at $z \sim 2-3$. For formation of LSS significantly earlier ($z \sim 6-8$) it is necessary to

include in Ω_{total} the density of vacuum energy (Λ-term). Our hypothesis about the formation of seeds for LSS is connected with the late relativistic phase transitions (RPT) in the gas of familon type pseudo-Goldstone bosons (pseudo-GB) which are a probable candidate in dark matter (DM).

The foundation of RPT theory has been formulated by Kirzhnits and Linde and cosmological application of this theory is used many authors. The time of the beginning of these RPT depends on a mass of familons. If $m_{GB} > 3 \times 10^{-4}\ eV$ then the essential influence of these RPT may take place in no far last evolution of our Universe. If $m_{GB} < 3 \times 10^{-4}\ eV$ then similar influence of these RPT may take place in the nearest cosmological future when $T_{CMB} < 2.7\ K$. We suppose that our particles theory of RPT in the gas and the vacuum of pseudo-GB allows more effectively to obtain $\delta\rho/\rho \sim 1$ on earlier stage of the Universe evolution ($z > 5$) than the standard model.

We have investigated the cosmological consequenses of the simplest boson-fermion model of quarks and leptons [1]. Our interest to the preon model was induced by the fact of possible leptoquarks resonance in the experiment HERA [2]. We have researched more detail the structure of preon nonperturbative vacuum arising in the result of the correlation of nonabelian fields on two scales ($\Lambda_{mc} \gg 1\ Tev$ is the confinement scale of metacolour and $\Lambda_c \sim 150\ Mev$ is QCD scale). We have detected that in spectrum of excitations of heterogenic nonperturbative preon vacuum pseudo-GB modes of familon type occurs. Familons are created in the result of spontaneous breaking symmetry of quark-lepton generations. Nonrezo masses of familons are the result of superweak interactions with quark condensates. We consider these particles as the basic constituent of cosmological dark matter. The distinguishing characteristic of these particles is the availability of the residual $U(1)$ symmetry and possibility of it spontaneous breaking for temperatures $\frac{\Lambda_c}{\Lambda_{mc}} \sim 10^{-3}\ eV$ in the result of RPT.

We have proposed that this relativistic phase transition has direct relation to the production of primordial perturbations in DM the evolution of which leads to baryon large scale structure formation. The idea of RPT in the cosmological gas of pseudo-GB in connection with LSS problem was formulated by Frieman et al. [3]. Here we have investigated by quantitatively the preon-familon model of this RPT.

At the beginning we point more detail the astrophysical motivation of our theory. Observational data show that some baryon objects such as the quasars on $z \sim 4.69$ and $z \sim 4.41$ [4] and galaxies on $z > 5$ [4] were produced as minimum on redshifts $z \sim 6 \div 8$. This is the difficulty for standard CDM and CHDM model to produce their (the best fit is $z \sim 2 \div 3$ and observations provide the support of this). If early baryon cosmological structures produced on $z > 10$ then the key role must play DM particles with nonstandard properties. In standard model DM consists of ideal gas particles with $m \approx 0$ practically noninteracting with usual matter (till now they do not detected because of their superweak interaction with baryons and leptons).

Certainly a characteristic moment of the most of cosmological structures formation finishing remains the same ($z \sim 2 \div 3$) and the appearence of baryon structures on high z ($z > 4$) will be a result of statistical outburst evolution of the spectrum of DM density perturbations. Early cosmological baryon structures are connected to statistical outbursts in sharp nonlinear physical system which is RPT (the production of inhomogeneities). For clearity we note again that the appearence of early baryon cosmological structures is the consequense of evolution of inhomogeneities on boundary of phase domains then as general situation of RPT in familon gas leads to "natural" picture of the formation of baryon LSS ($z \sim 2 \div 3$). In frame of our theory some unclear questions of the astrophysical interpretation of globular clusters age, distribution of early baryon structures (quasars, CO clouds, galaxies) may be understood and next generation of space instruments (Next Generation

Space Telescope, Far-Infrared and Submillimeter Space Telescope) will help to do this.

A new theory of DM must combain properties of superweak interaction of DM particles with baryons and leptons and intensive interaction of theses particles each other. Such interactions are provided by nonlinear properties of DM medium. This is the condition for realization of RPT.

The familon symmetry is experimentally observed (the different generations of quarks and leptons participate in gauge interactions the same way). Breaking of this symmetry gives a mass of particles in different generations. A hypothesis about spontaneous breaking of familon symmetry is natural and the origin of Goldstone bosons is inevitably. The properties of any pseudo-GB as and pseudo-GB of familon type depends on physical realization of Goldstone modes. These modes can be arisen from fundamental Higgs fields or from collective excitations of a heterogenic nonperturbative vacuum condensate more complex than quark-gluon one in QCD. The second possibility can realize the theory in which quarks and leptons are composite that is the preon model of elementary particles. If leptoquarks will be detected then two variants of explanations may be. If leptoquarks resonanse will be narrow and high then theses leptoquarks come from GUT or SUSY theories. The low and wide resonanse can be explained by composite particles only (preons).

Thus, in frame of preon theory DM is interpretated as a system of familon collective excitations of a heterogenic nonperturbative vacuum. This system consists of 3 subsystems:

1) familons of up-quark type;

2) familons of down-quark type;

3) familons of lepton type.

On stages of cosmological evolution when $T \ll \Lambda_{mc}$ the heavy unstable familons are absent. Small masses of familons are the result of superweak interactions of

Goldstone fields with nonperturbative vacuum condensates and therefore familons acquire status of pseudo-GB.

The value of these masses is limited by astrophysical and laboratory magnitudes [5]:

$$m_{astrophysical} \sim 10^{-3} \div 10^{-5}\ eV \tag{1}$$

$$m_{laboratory} \leq 10\ eV$$

The effect of familons mass production corresponds formally mathemathically the appearence of mass terms in the Lagrangian of Goldstone fields. From general considerations one can propose that mass-terms may arise as with "right" as and with "wrong" signs. The sign of the mass-terms predetermines the destiny of residual symmetry of Goldstone fields. In the case of "wrong" sign for low temperatures $T < T_c \sim m_{familons} \sim 0.1 \div 10^5\ K$ a Goldstone condensate produces and the symmetry of the familon gas breaks spontaneously.

The representation about physical nature of familon excitations described above is formalized in a theoretical-field model. As example we discuss a model only one familon subsystem corresponding to up- quarks of second and third generations. The chiral-familon group of the model is $SU_L(2) \times SU_R(2)$. The familon excitations are described by eight measure (on number of matrix components) reducible representation of this group factorized on two irreducible representations $(F, f_a);\ (\psi, \varphi_a)$ which differ each other by a sign of space chirality. In this model the interaction of quark fields with familons occurs. However in all calculations quark fields are represented in the form of nonperturbative quark condensates. From QCD and a experiment the connection between quark and gluon condensates is known:

$$\langle 0 \mid \bar{q}q \mid 0 \rangle \approx \frac{1}{12 m_q} \qquad \langle 0 \mid \frac{\alpha_s}{\pi} G^n_{\mu\nu} G^{\mu\nu}_n \mid 0 \rangle \approx \frac{3\Lambda_c^4}{4 m_q} \tag{2}$$

Here: $q = t, c;\ \ m_c \sim 1.5\ Gev;\ \ m_t \sim 175\ Gev;\ \ \Lambda_c \sim 150\ Mev.$

The spontaneous breaking of symmetry $SU_L(2) \times SU_R(2) \to U(1)$ is produced by vacuum shifts $\langle \psi \rangle = v$; $\langle f_3 \rangle = u$. The numerical values $v, u \sim \Lambda_{mc}$ are unknown. They must be found by experimentally if our theory corresponds to reality. Parameters u and v together with the value of condensates (2) define numerical values of basic magnitudes characteristing the familon subsystem. After breaking of symmetry $SU_L(2) \times SU_R(2) \to U(1)$ light pseudo-GB fields contain the real pseudoscalar field with the mass:

$$m_{\varphi'}^2 = \frac{1}{6(u^2+v^2)} \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \tag{3}$$

the complex pseudoscalar field with the mass:

$$m_{\varphi}^2 = \frac{1}{24v^2} \frac{m_t}{m_c} \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \tag{4}$$

and complex scalar field the mass square of which is negative:

$$m_f^2 = -\frac{1}{24u^2} \frac{m_t}{m_c} \langle 0 \mid \frac{\alpha_s}{\pi} G_{\mu\nu}^n G_n^{\mu\nu} \mid 0 \rangle \tag{5}$$

Complex field with masses (4-5) are the nontrivial representation of residual symmetry of $U(1)$ group, but the real field (3) is the sole representation of this group. We propose that cosmological DM consists of particles with these masses and their analogies from the down- quark-familon and lepton-familon subsystems.

The negative square of mass of complex scalar field means that for

$$T < T_{c(up)} \sim \mid \bar{m}_f \mid \sim \frac{\Lambda_c^2}{\Lambda_{mc}} \sqrt{m_t/m_c} \tag{6}$$

pseudogoldstone vacuum is unstable that is when $T = T_{c(up)}$ in gas of pseudogoldstone bosons should be the RPT in a state with spontaneous breaking $U(1)$ symmetry. Two other familon subsystems can be studied by the same methods. Therefore DM consisting of pseudo-GB of familon type is a many component heterogenic system evolving complex thermodynamical way.

In the phase of breaking symmetry every complex field with masses (4-5) splits on two real fields with different masses. That is the familon subsystem of up-quark type consists from five kinds of particles with different masses. Analogous phenomenon takes place in the down-quark subsystem. The breaking of residual symmetry is when

$$T_{c(down)} \sim \frac{\Lambda_c^2}{\Lambda_{mc}} \sqrt{m_b/m_s} \tag{7}$$

In the low symmetric phase this subsystem consists also of five kinds particles with different masses. In our theory the lepton-familon subsystem is not undergone RPT therefore it consists of particles and antiparticles of 3 kinds with 3 different masses.

The relativistic phase transitions in familon subsystems must be described in frame of temperature quantum field theory. It is important to underline that sufficiently strong interactions of familons each other provide the evolution of familon subsystem through state of local equilibrium type. Our estimates have shown that the transition in nonthermodynamical regime of evolution occurs on stage after RPT even if RPT took place for temperature $\sim 10^{-3}\ eV$. The thermodynamics of familon system may be formulated in approximation of the self-coordinated field. The methods of the RPT theory which will be used by us are similar to ones of our article [6]. The unequilibrium Landau functional of states $F(T, \eta, m_A)$ depends on symmetry order parameter η and five effective masses of particles $m_A,\ A = 1, 2, 3, 4, 5$

$$F(T, \eta, m_A) = -\frac{1}{3} \sum_A J_2(T, m_A) + U(\eta, m_A) \tag{8}$$

Here J_2 is the characteristic integrals (similar integrals were used for the description of RPT in our article [7]). The conditions of extremum of functional on effective masses give the equation of connection $m_a = m_a(\eta, T)$ which formal

defines the typical functional Landau $F(T,\eta)$. The condition of minimum of this functional on the parameter of order

$$\frac{d^2F}{d\eta^2} = \frac{\partial^2 F}{\partial\eta^2} + \sum_A \frac{\partial^2 F}{\partial\eta\partial m_A}(\frac{\partial m_A}{\partial\eta}) > 0 \tag{9}$$

is concordanced with equation of state $\partial F/\partial\eta = 0$ that allows: a) to establish the kind of RPT, b) to find thermodynamical boundary of stability phases, c) to calculate values of observed magnitudes (energy density, pressure, thermal capacity, sound velocity et al.) in each phase.

We have detected that RPT in familon gas is RPT of first kind with wide region of phases coexistence. Therefore in epoch RPT or more exactly in region phase coexistence the Universe had block-phase structure containing domains of different phases. The numerical modelling of this RPT [8] has shown that average contrast of density in the block-phase structure is $\delta\epsilon/\epsilon \sim 1$.

The size of domains and masses of baryon and dark matter inside domains are defined by distance to horison of events $L_{horiz.}$ at moment of RPT. As it is seen from (6-7) numerical values of these magnitudes which are important for LSS theory depend on values of unknown today parameter of preon confainment Λ_{mc}.

If inhomogeneties appearing during RPT in familon gas have the relation to observable scales of LSS (10 Mpc) then $\Lambda_{mc} \sim 10^5\ Tev$. More detail estimates today is premature but it is necessary to note that suggested theory contains two phase transitions and therefore two characteristic scales of LSS. Here also it is necessary to underline that a catastrophic phenomenon in familon gas could not influence on spectrum of relic radiation even if $m_f \geq 0.4\ eV$ due to superweak interaction familons with the usual matter but effects connected with the fragmentation of DM medium may be superimposed at the spectrum of CMB radiation.

Numerical estimates of inhomogeneities parameters arising as the result of strong interaction of domains LS and HS phases in region of their contact show that $\delta\epsilon/\epsilon \sim 1$ on scale $L \sim 0.1 L_{horison}$ at the moment of the phase transition.

The more detail publications can be found in [8-9].

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